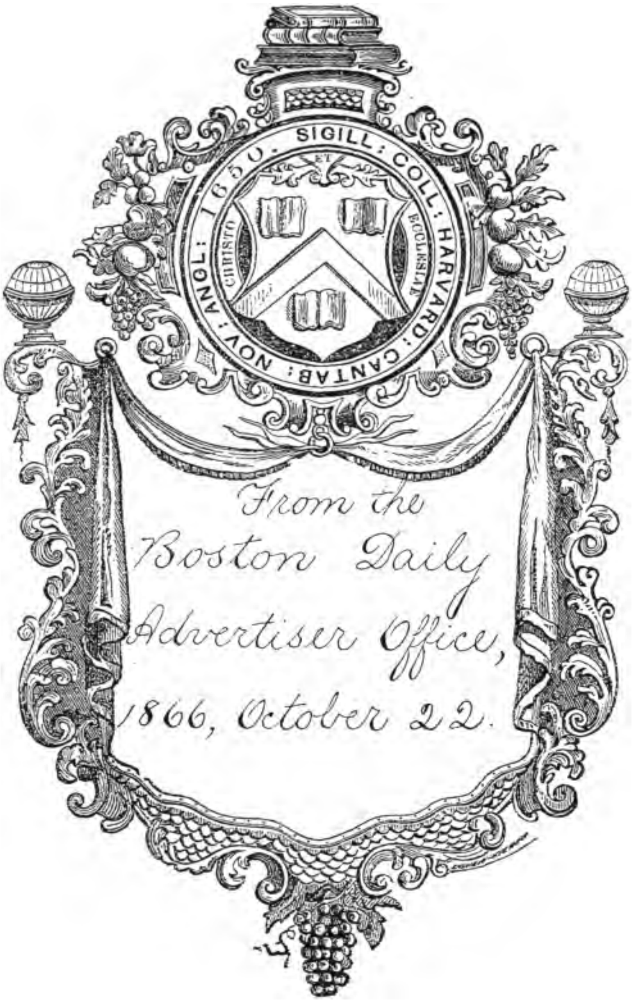
SIGILL: COLL: HARVARD: CANTAB: NOV: ANGL: 1650.
CHRISTO ET ECCLESIAE
From the
Boston Daily
Advertiser Office,
1866, October 22.

ATLANTIC TELEGRAPH CABLE.

1866. Oct. 22
From the
Boston Daily Advertiser Office.

ADDRESS

OF

PROFESSOR WILLIAM THOMSON,

LL.D., F.R.S.,

DELIVERED BEFORE THE

ROYAL SOCIETY OF EDINBURGH,

December 18*th*, 1865.

WITH OTHER DOCUMENTS.

LONDON:
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1866.

INDEX TO DOCUMENTS WITH PROFESSOR THOMSON'S ADDRESS.

PROCEEDINGS

OF THE

ROYAL SOCIETY OF EDINBURGH.

Monday, December 18th, 1865.

SIR DAVID BREWSTER, President, in the Chair.

At the request of the Council, Professor WILLIAM THOMSON, LL.D., of Glasgow, delivered the following Address on the Forces concerned in the Laying and Lifting of Deep-sea Cables.

THE forces concerned in the laying and lifting of deep submarine cables attracted much public attention in the years 1857-58.

An experimental trip to the Bay of Biscay in May, 1858, proved the possibility, not only of safely laying such a rope as the old Atlantic cable in very deep water, but of lifting it from the bottom without fracture. The speaker had witnessed the almost incredible feat of lifting up a considerable length of that slight and seemingly fragile thread from a depth of nearly 2½ nautical miles.* The cable had actually brought with it safely to the surface, from the bottom, a splice with a large weighted frame attached to it, to prevent untwisting between the two ships, from which two portions of cable with opposite twists had been laid. The actual laying of the cable a few months later, from mid ocean to Valentia on one side, and Trinity Bay, Newfoundland, on the other, regarded

* Throughout the following statements, the word mile will be used to denote (not that most meaningless of modern measures, the British statute mile) but the nautical mile, or the length of a minute of latitude, in mean latitudes, which in electric cable reckoning is taken as 6,073 feet. For approximate statements, rough estimates, &c., it may be taken as 6,000 feet, or 1,000 fathoms.

merely as a mechanical achievement, took by surprise some of the most celebrated engineers of the day, who had not concealed their opinion, that the Atlantic Telegraph Company had undertaken an impossible problem. As a mechanical achievement it was completely successful; and the electric failure, after several hundred messages (comprising upwards of 4,359 words) had been transmitted between Valentia and Newfoundland, was owing to electric faults existing in the cable before it went to sea. Such faults cannot escape detection, in the course of the manufacture, under the improved electric testing since brought into practice, and the causes which led to the failure of the first Atlantic cable no longer exist as dangers in submarine telegraphic enterprise. But the possibility of damage being done to the insulation of the electric conductor before it leaves the ship (illustrated by the occurrences which led to the temporary loss of the 1865 cable), implies a danger which can only be thoroughly guarded against by being ready at any moment to back the ship and check the egress of the cable, and to hold on for some time, or to haul back some length according to the results of electric testing.

The forces concerned in these operations, and the mechanical arrangements by which they are applied and directed, constitute one chief part of the present address; the remainder is devoted to explanations as to the problem of lifting the west end of the 1,200 miles of cable laid last summer, from Valentia westwards, and now lying in perfect electric condition (in the very safest place in which a submarine cable can be kept), and ready to do its work, as soon as it is connected with Newfoundland, by the 600 miles required to complete the line.

Forces concerned in the Submergence of a Cable.

In a paper published in the "Engineer" Journal in 1857, the speaker had given the differential equations of the catenary formed by a submarine cable between the ship and the bottom, during the submergence, under the influence of gravity and fluid friction and pressure; and he had pointed out that the curve becomes a straight line in the case of no tension at the bottom. As this is always the case in deep sea cable laying, he made no further reference to the general problem in the present address.

When a cable is laid at uniform speed, on a level bottom, quite straight, but without tension, it forms an inclined straight line, from the point where it enters the water, to the bottom, and each point of it clearly moves uniformly in a straight line towards the position on the bottom that it ultimately occupies.* That is to say, each particle of the cable moves uniformly along the base of an isosceles triangle, of which the two equal sides are the inclined portion of the

* Precisely the movement of a battalion in line changing front.

cable between it and the bottom, and the line along the bottom which this portion of the cable covers when laid. When the cable is paid out from the ship at a rate exceeding that of the ship's progress, the velocity and direction of the motion of any particle of it through the water are to be found by compounding a velocity along the inclined side, equal to this excess, with the velocity already determined, along the base of the isosceles triangle.

The angle between the equal sides of the isosceles triangle, that is to say, the inclination which the cable takes in the water, is determined by the condition, that the transverse component of the cable's weight in water is equal to the transverse component of the resistance of the water to its motion. Its tension where it enters the water is equal to the longitudinal component of the weight (or, which is the same, the whole weight of a length of cable hanging vertically down to the bottom), diminished by the longitudinal component of the fluid resistance. In the laying of the Atlantic cable, when the depth was two miles, the rate of the ship six miles an hour, and the rate of paying out of the cable seven miles an hour, the resistance to the egress of the cable, accurately measured by a dynamometer, was only 14 cwt. But it must have been as much as 28 cwt., or the weight of two miles of the cable hanging vertically down in water, were it not for the frictional resistance of the water against the cable slipping, as it were, down an inclined plane from the ship to the bottom, which therefore must have borne the difference, or 14 cwt. Accurate observations are wanting as to the angle at which the cable entered the water; but from measurements of angles at the stern of the ship, and a dynamical estimate (from the measured strain) of what the curvature must have been between the ship and the water, I find that its inclination in the water, when the ship's speed was nearly $6\frac{1}{2}$ miles per hour, must have been about $6\frac{3}{4}°$, that is to say, the incline was about 1 in $8\frac{1}{2}$. Thus the length of cable, from the ship to the bottom, when the water was two miles deep, must have been about 17 miles.

The whole amount (14 cwt.) of fluid resistance to the motion of this length of cable through it is therefore about ·81 of a cwt. per mile. The longitudinal component velocity of the cable through the water, to which this resistance was due, may be taken, with but very small error, as simply the excess of the speed of paying out above the speed of the ship, or about one mile an hour. Hence, to haul up a piece of the cable vertically through the water, at the rate of one mile an hour, would require less than 1 cwt. for overcoming fluid friction, per mile length of the cable, over and above its weight in water. Thus fluid friction, which for the laying of a cable performs so valuable a part in easing the strain with which it is paid out, offers no serious obstruction, indeed, scarcely any sensible obstruction, to the reverse process of hauling back, if done at only one mile an hour, or any slower speed.

As to the transverse component of the fluid friction, it is to be remarked that,

although not directly assisting to reduce the egress strain, it indirectly contributes to this result; for it is the transverse friction that causes the gentleness of the slope, giving the sufficient length of 17 miles of cable slipping down through the water, on which the longitudinal friction operates, to reduce the egress strain to the very safe limit found in the recent expedition. In estimating its amount, even if the slope were as much as 1 in 5, we should commit only an insignificant error, if we supposed it to be simply equal to the weight of the cable in water, or about 14 cwt. per mile for the 1865 Atlantic cable. The transverse component velocity to which this is due may be estimated with but insignificant error, by taking it as the velocity of a body moving directly to the bottom in the time occupied in laying a length of cable equal to the 17 miles of oblique line from the ship to the bottom. Therefore, it must have been from 2 miles in $17 \div 6\frac{1}{2} = 2{\cdot}61$ hours, or ·8 of a mile per hour. It is not probable that the actual motion of the cable lengthwise through the water can affect this result much. Thus, the *velocity of settling* of a horizontal piece of the cable (or velocity of sinking through the water, with weight just borne by fluid friction) would appear to be about ·8 of a mile per hour. This may be contrasted with longitudinal friction by remembering that, according to the previous result, a longitudinal motion through the water at the rate of one mile per hour is resisted by only 1-17th of the weight of the portion of cable so moving.

These conclusions justify remarkably the choice that was made of materials and dimensions for the 1865 cable. A more compact cable (one for instance with less gutta percha, less or no tow round the iron wires, and somewhat more iron), even if of equal strength and equal weight per mile in water, would have experienced less transverse resistance to motion through the water, and therefore would have run down a much steeper slope to the bottom. Thus, even with the same longitudinal friction per mile, it would have been less resisted on the shorter length; but even on the same length it would have experienced much less longitudinal friction, because of its smaller circumference. Also, it is important to remark that the roughness of the outer tow covering undoubtedly did very much to ease the egress strain, as it must have increased the fluid friction greatly beyond what would have acted on a smooth gutta percha surface, or even on the surface of smooth iron wires, presented by the more common form of submarine cables.

The speaker showed models illustrating the paying-out machines used on the Atlantic expeditions of 1858 and 1865. He stated that nothing could well be imagined more perfect than the action of the machine of 1865 in paying out the 1,200 miles of cable then laid, and that if it were only to be used for *paying out*, no change either in general plan or in detail seemed desirable, except the substitution of a softer material for the "jockey pulleys," by which the cable in entering the machine has the small amount of resistance applied to it which

it requires to keep it from slipping round the main drum. The rate of egress of the cable was kept always under perfect control by a weighted friction brake of Appold's construction (which had proved its good quality in the 1858 Atlantic expedition) applied to a second drum carried on the same shaft with the main drum. When the weights were removed from the brake (which could be done almost instantaneously by means of a simple mechanism), the resistance to the egress of the cable, produced by "jockey pulleys," and the friction at the bearings of the shaft carrying the main drum, &c., was about 2½ cwt.

Procedure to repair the Cable in case of the appearance of an electric fault during the laying.

In the event of a fault being indicated by the electric test at any time during the paying out (as proved by the recent experience), the safe and proper course to be followed in future, if the cable is of the same construction as the present Atlantic cable, is instantly, on order given from an authorised officer in the electric room, to stop and reverse the ship's engines, and to put on the greatest *safe* weight on the paying-out brake. Thus in the course of a very short time the egress of the cable may be stopped, and, if the weather is moderate, the ship may be kept, by proper use of paddles, screw, and rudder, nearly enough in the proper position for hours to allow the cable to hang down almost vertically, with little more strain than the weight of the length of it between the ship and the bottom.

The best electric testing that has been practised, or even planned, cannot show within a mile the position of a fault consisting of a slight loss of insulation, unless both ends of the cable are at hand. Whatever its character may be, unless the electric tests demonstrate its position to be remote from the outgoing part, the only thing that can be done to find whether it is just on board or just overboard, is to cut the cable as near the outgoing part as the mechanical circumstances allow to be safely done. The electric test immediately transferred to the fresh-cut seaward end shows instantly if the electric line is perfect between it and the shore. A few minutes more, and the electric tests applied to the *two ends* of the remainder on board, will, in skilful hands, with a proper plan of working, show very closely the position of the fault, *whatever its character may be*. The engineers will thus immediately be able to make proper arrangements for re-splicing and paying out good cable, and for cutting out the fault from the bad part.

But if the fault is between the land end and the fresh-cut seaward end on board ship, proper simultaneous electric tests on board ship and on shore (not hitherto practised, but easy and sure if properly planned) must be used to discover whether the fault lies so near the ship that the right thing is to haul back

the cable until it is got on board. If it is so, then steam power must be applied to reverse the paying-out machine, and, by careful watching of the dynamometer, and controlling the power accordingly (hauling in slowly, stopping, or veering out a little, but never letting the dynamometer go above 60 or 65 cwt.), the cable (which can bear 7 tons) will not break, and the fault will be got on board more surely, and possibly sooner, than a "sulky" salmon of 30 lbs. can be landed by an expert angler with a line and rod that could not bear 10 lbs. The speaker remarked that he was entitled to make such assertions with confidence now, because the experience of the late expedition had not only verified the estimates of the scientific committee, and of the contractors, as to the strength of the cable, its weight in water (whether deep or shallow), and its mechanical manageability, but it had proved that in moderate weather the "Great Eastern" could, by skilful seamanship, be kept in position and moved in the manner required. She had actually been so for thirty-eight hours, and eighteen hours during the operations involved in the hauling back and cutting out the first and second faults, and re-uniting the cable, and during seven hours of hauling in, in the attempt to repair the third fault.

Should the simultaneous electric testing on board and on shore prove the fault to be 50 or 100 or more miles from the ship, it would depend on the character of the fault, the season of the year, and the means and appliances on board, whether it would be better to complete the line, and afterwards, if necessary, cut out the fault and repair, or to go back at once and cut out the fault before attempting to complete the line. Even the worst of these contingencies would not be fatal to the undertaking with such a cable as the present one. But all experience of cable-laying shows that almost certainly the fault would either be found on board, or but a very short distance overboard, and would be reached and cut out with scarcely any risk, if really prompt measures, as above described, are taken at the instant of the appearance of a fault, to stop as soon as possible with safety the further egress of the cable.

The most striking part of the Atlantic undertaking proposed for 1866, is that by which the 1,200 miles of excellent cable laid in 1865 is to be utilised by completing the line to Newfoundland.

That a cable lying on the bottom in water two miles deep can be caught by a grapnel and raised several hundred fathoms above the bottom, was amply proved by the nine days' work which followed the breakage of the cable on the 2nd of August last. Three times out of four that the grapnel was let down, it caught the cable on each occasion after a few hours of dragging, and with only 300 or 400 fathoms more of rope than the 2,100 required to reach the bottom by the shortest course. The time when the grapnel did not hook the cable it came up with one of its flukes caught round by its chain; and the grapnel, the short length of chain next it, and about 200 fathoms of the wire rope, were proved

to have been dragged along the bottom, by being found, when brought on board, to have the interstices filled with soft light gray ooze (of which the speaker showed a specimen to the Royal Society). These results are quite in accordance with the dynamical theory indicated above, according to which a length of such rope as the electric cable, hanging down with no weight at its lower end, and held by a ship moving through the water at half a mile an hour, would slope down to the bottom at an angle from the vertical of only 20°; and the much heavier and denser wire-rope that was used for the grappling would go down at the same angle with a considerably more rapid motion of the ship, or at a still steeper slope with the same rate of motion of the ship.

The only remaining question is: How is the cable to be brought to the surface when hooked? The operations of last August failed from the available rope, tackle, and hauling machine not being strong enough for this very unexpected work. On no occasion was the electric cable broken.* With strong enough tackle, and a hauling machine, both strong enough, and under perfect control, the lifting of a submarine cable, as good in mechanical quality as the Atlantic cable of 1865, by a grapnel or grapnels, from the bottom at a depth of two miles, is certainly practicable. If one attempt fails another will succeed; and there is every reason, from dynamics as well as from the 1865 experience, to believe that in any moderate weather the feat is to be accomplished with little delay, and with very few if any failing attempts.

The several plans of proceeding that have been proposed are of two classes—those in which, by three or more ships, it is proposed to bring a point of the cable to the surface without breaking it at all; and those in which it is to be cut or broken, and a point of the cable somewhat eastward from the break is to be brought to the surface.

With reference to either class, it is to be remarked that, by lifting simultaneously by several grapnels so constructed as to hold the cable without slipping along it or cutting it, it is possible to bring a point of the cable to the surface without subjecting it to any strain amounting to the weight of a length of cable equal to the depth of the water. But so many simultaneous grapplings by ships crossing the line of cable at considerable distances from one another would be required, that this possibility is scarcely to be reckoned on practically, without

* The strongest rope available was a quantity of rope of iron wire and hemp spun together, able to bear 14 tons, which was prepared merely as *buoy-rope* (to provide for the contingency of being obliged, by stress of weather or other cause, to cut and leave the cable in deep or shallow water), and was accordingly all in 100 fathom lengths, joined by shackles with swivels. The wire-rope itself never broke, but on two of the three occasions a swivel gave way. On the last occasion about 900 fathoms of Manilla rope had to be used for the upper part, there not being enough of the wire buoy-rope left; and when 700 fathoms of it had been got in, it broke on board beside a shackle, and the remaining 200 fathoms of the Manilla, with 1,540 fathoms of wire-rope and the grapnel, and the electric cable which it had hooked, were all lost for the year 1865.

cutting or breaking the cable at a point westward of the points raised by the grapnels. On the other hand, with but three ships the cable might, no doubt, be brought to the surface at any point along the line, without cutting it, and without subjecting it at any point to *much* more strain than the weight corresponding to the vertical depth, as is easily seen when it is considered that the cable was laid generally with from 10 to 15 per cent. of slack. And if the cable is cut at some point not far westward of the westernmost of the grapnels, there can be no doubt but it could be lifted with great ease by three grapnels hauled up simultaneously by three ships. The catenaries concerned in these operations were illustrated by a chain with 15 per cent. of slack hauled up simultaneously at three points.

The plan which seems to the speaker surest and simplest is to cut the cable at any chosen point, far enough eastward of the present broken end to be clear of entanglement of lost buoy-rope, grapnels, and the loose end of the electric cable itself; and then, or as soon as possible after, to grapple and lift at a point about three miles farther eastward. This could be well and safely done by two ships, one of them with a cutting grapnel, and the other (the "Great Eastern" herself) with a holding grapnel. The latter, on hooking, should haul up cautiously, never going beyond a safe strain, as shown by the dynamometer. The other, when assured that the "Great Eastern" has the cable, should haul up, at first cautiously, but ultimately, when the cable is got well off the bottom by the "Great Eastern," the western ship should move slowly eastwards, and haul up with force enough to cut or break the cable. This leaves three miles of free cable on the western side of the "Great Eastern's" grapnel, which will yield freely eastwards (even if partly lying along the bottom at first), and allow the "Great Eastern" to haul up and work slowly eastwards, so as to keep its grappling rope, and therefore ultimately the portions of electric cable hanging down on the two sides of its grapnel, as nearly vertical as is necessary to make sure work of getting the cable on board. This plan was illustrated by lifting, by aid of two grapnels, a very fragile chain (a common brass chain in short lengths, joined by links of fine cotton thread) from the floor of the Royal Society. It was also pointed out that it can be executed by one ship alone, with only a little delay, but with scarcely any risk of failure. Thus, by first hooking the cable by a holding grapnel, and hauling it up 200 or 300 fathoms from the bottom, it may be left there hanging by the grapnel-rope on a buoy, while the ship proceeds three miles westwards, cuts the cable there, and returns to the buoy. Then it is an easy matter, in any moderate weather, to haul up safely and get the cable on board.

The use of the dynamometer in dredging was explained; and the forces operating on the ship, the conditions of weather, and the means of keeping the ship in proper position during the process of slowly hauling in a cable, even if it

were of strength quite insufficient to act when nearly vertical with any sensible force on the ship, were discussed at some length. The manageability of the "Great Eastern," in skilful hands, had been proved to be very much better than could have been expected, and to be sufficient for the requirements in moderate weather. She has both screw and paddles—an advantage possessed by no other steamer in existence. By driving the screw at full power ahead, and backing the paddles, to prevent the ship from moving ahead, or (should the screw overpower the paddles), by driving the paddles full power astern, and driving at the same time the screw ahead with power enough to prevent the ship from going astern, "steerage way" is *created* by the lash of water from the screw against the rudder; and thus the "Great Eastern" may be effectually steered without going ahead. Thus she is, in calm or moderate weather, almost as manageable as a small tug steamer, with reversing paddles, or as a rowing boat. She can be made still more manageable than she proved to be in 1865, by arranging to disconnect either paddle at any moment; which, the speaker was informed by Mr. Canning, may easily be done. *

The speaker referred to a letter he had received from Mr. Canning, Chief Engineer of the Telegraph Construction and Maintenance Company, informing him that it is intended to use three ships, and to be provided both with cutting and with holding grapnels, and expressing great confidence as to the success of the attempt. *In this confidence the speaker believed every practical man who witnessed the Atlantic operations of* 1865 *shared, as did also, to his knowledge, other engineers who were not present on that expedition, but who were well acquainted with the practice of cable-laying and mending in various seas, especially in the Mediterranean. The more he thought of it himself, both from what he had witnessed on board the "Great Eastern," and from attempts to estimate on dynamical principles the forces concerned, the more confident he felt that the contractors would succeed next summer in utilising the cable partly laid in* 1865, *and completing it into an electrically perfect telegraphic line between Valentia and Newfoundland.*

* It is being done.

(A.)

ATLANTIC TELEGRAPH CABLE.

Certificate signed by persons officially engaged in laying the Atlantic Telegraph Cable from the Great Eastern in 1865.

1. It was proved by the expedition of 1858, that a Submarine Telegraph Cable could be laid between Ireland and Newfoundland, and messages transmitted through the same.

By the expedition of 1865 it has been fully demonstrated :—

2. That the insulation of a cable improves very much after its submersion in the cold deep water of the Atlantic, and that its conducting power is considerably increased thereby.

3. That the steamship Great Eastern, from her size and constant steadiness, and from the control over her afforded by the joint use of paddles and screw, renders it safe to lay an Atlantic Cable in any weather.

4. That in a depth of over two miles four attempts were made to grapple the cable. In three of them the cable was caught by the grapnel, and in the other the grapnel was fouled by the chain attached to it.

5. That the paying-out machinery used on board the Great Eastern worked perfectly, and can be confidently relied on for laying cables across the Atlantic.

6. That with the improved Telegraphic instruments for long submarine lines, a speed of more than eight words per minute can be obtained through such a cable as the present Atlantic between Ireland and Newfoundland, as the amount of slack actually paid out did not exceed 14 per cent., which would have made the total cable laid between Valentia and Heart's Content, less than 1,900 miles.

7. That the present Atlantic Cable, though capable of bearing a strain of 7 tons, did not experience more than 14 cwt. in being paid out into the deepest water of the Atlantic between Ireland and Newfoundland.

8. That there is no difficulty in mooring buoys in the deep water of the Atlantic between Ireland and Newfoundland, and that two buoys even when moored by a piece of the Atlantic Cable itself, which had been previously lifted from the bottom, have ridden out a gale.

9. That more than four nautical miles of the Atlantic Cable have been recovered from a depth of over two miles, and that the insulation of the gutta percha covered wire was in no way whatever impaired by the depth of water or the strains to which it had been subjected by lifting and passing through the hauling-in apparatus.

10. That the cable of 1865, owing to the improvements introduced into the manufacture of the gutta percha core, was more than one hundred times better insulated than cables made in 1858, then considered perfect and still working.

11. That the electrical testing can be conducted at sea with such unerring accuracy as to enable the electricians to discover the existence of a fault immediately after its production or development, and very quickly to ascertain its position in the cable.

12. That with a steam-engine attached to the paying-out machinery, should a fault be discovered on board whilst laying the cable, it is possible that it might be recovered before it had reached the bottom of the Atlantic, and repaired at once.

S. CANNING *(Engineer in Chief, Telegraph Construction and Maintenance Company, Limited.)*

JAMES ANDERSON *(Commander of the Great Eastern)*.

HENRY A. MORIARTY, *(Staff Commander, R.N.)*

DANIEL GOOCH, M.P. *(Chairman of "Great Ship Co.")*.

HENRY CLIFFORD *(Engineer)*.

WILLIAM THOMSON, LL.D., F.R.S. *(Prof. of Natural Philosophy in the University of Glasgow)*.

CROMWELL F. VARLEY *(Consulting Electrician Electric and International Telegraph Co.)*.

WILLOUGHBY SMITH.

JULES DESPECHER.

(B.)

Certificate from Prospectus of the

ANGLO-AMERICAN TELEGRAPH COMPANY, Limited.

The Directors cannot of course bind themselves at present to any tariff for messages. The amount to be charged will be a matter for consideration hereafter. But it may be safely assumed that it will not be less than 5s. per word. Working at 5s. per word, only five words a minute, twenty-four hours per day, and allowing 300 working days for the year, there would be a gross revenue of £1,800 a-day, or £540,000 a year. This is for one cable only.

The highest authorities in Electrical Science give it as their opinion that eight words a minute could easily be obtained through the Atlantic Cable. And there is every reason to anticipate that at a tariff of anything like 5s. a word there would be more messages offered than the Company could transmit.

The undersigned append their names as considering this Estimate of the probable result a reasonable one.

CHARLES T. BRIGHT, M.I.C.E.,
Consulting Engineer to the British and Irish Magnetic Telegraph Company.

LATIMER CLARK, M.I.C.E.,
Consulting Engineer to the Electric and International Telegraph Company.

HENRY C. FORDE, M.I.C.E.

FLEEMING JENKIN, F.R.S.

WILLIAM THOMSON, LL.D., F.R.S.,
Professor of Natural Philosophy in the University of Glasgow.

CROMWELL F. VARLEY, M.I.C.E., F.R.G.S., M.R.I., &c., &c.,
Electrician to the Electric and International Telegraph Company.

The realisation of this Estimate (allowing £25,000 per annum for Working Expenses) would make the income of the Company over £300,000 per annum.

(C

Estimated Revenue based upon the opinion of the highest authorities in Electrical Science. Assuming that the charge for transmission of Messages between the Old and the New World be fixed at 5s. *per word, and that the speed of working be limited to only* 5 *words per minute during* 24 *hours per day, and allowing* 300 *working days in the year,*

ONE CABLE

Would produce a gross Annual Revenue of £540,000, to be divided as follows:—

1.	Working Expenses (say)		£25,000
2.	Interest at 5 per Cent. on £100,000 Atlantic Telegraph Debentures		5,000
3.	Anglo-American Telegraph Company		125,000
4.	Atlantic Telegraph Company's Preference Shares £600,000, 8 per Cent.		48,000
5.	Atlantic Telegraph Company's Ordinary Shares £600,000 4 per Cent.		24,000
6.	Balance divided	Anglo-American Telegraph Co.	156,500
		Atlantic Telegraph Co.	156,500
			£540,000

To the £281,000 above shown as coming to the Anglo-American Telegraph Company from the revenue of the cable, the sum of £25,000 must be added, granted as a subsidy by the New York, Newfoundland and London Telegraph Company, which will make a total income of £306,500, or over 50 per Cent. net upon the capital of the Anglo-American Telegraph Company. After paying 8 per Cent. on the Atlantic Telegraph Company's Preference, and 4 per Cent. on the Ordinary Shares, there is a surplus for the Atlantic Telegraph Company of £156,500, which would pay a further dividend of 12 per Cent. on the full amount of both Stocks of that company, £144,000, and leave a sum to be carried to new account of £12,500. This is a total dividend to the Preference Shareholders of 20 per Cent., and to the Ordinary Shareholders of 16 per Cent. per annum.

(D.)

In the anticipated event of the Telegraph Construction and Maintenance Company succeeding in laying the new cable, in raising the end of the cable partly laid in 1865, *and completing it to Newfoundland, then upon the same basis of calculation as that made for one Cable,*

TWO CABLES

Would produce a gross Annual Revenue of £1,080,000, which would be divided as follows:—

1.	Working Expenses (say)	£30,000
2.	Interest at 5 per Cent. on £100,000 Atlantic Telegraph Debentures	5,000
3.	Anglo-American Telegraph Company..............	125,000
4.	Atlantic Telegraph Company Preference Shares, £600,000, 8 per Cent.	48,000
5.	Atlantic Telegraph Company Ordinary Shares £600,000, 4 per Cent.	24,000
6.	Balance divided { Anglo American Telegraph Co. ..	424,000
	Balance divided { Atlantic Telegraph Co.	424,000
		£1,080,000

The subsidy of £25,000 from the New York, Newfoundland and London Telegraph Company being added to the £549,000 coming as above to the Anglo-American Telegraph Company from the revenue of the two cables will make the income of the latter £574,000, or over 95 per Cent. net upon the capital of the Anglo-American Telegraph Company. After paying 8 per Cent. on the Atlantic Telegraph Company's Preference, and 4 per Cent. on the Ordinary Shares, there is a surplus for the Atlantic Telegraph Company of £424,000, which would pay a further dividend of 35 per Cent. on both Stocks of that Company, and leave a sum of £4,000 to be carried to New Account, making a total dividend to the Preference Shareholders of 43 per Cent., and to the Ordinary Shareholders of 39 per Cent.

(E.)

Extract from Letter of Mr. Cromwell F. Varley to the "Observer," dated March 3rd, 1866.

* * * The best preservative of gutta percha is sea water. Failure of cables already laid prove no deterioration of the gutta percha; it has proceeded from imperfect joints and imperfect manufacture. The Dover and Calais Cable, laid in 1851, is still doing its duty. These latter sources of failure are now entirely overcome, thanks to Samuel Statham, John Chatterton, Willoughby Smith, and those scientific gentlemen who have devised methods as well as apparatus for hunting out minute faults, even when they have been so small that they would not weaken the signals through the Atlantic Cable one-millionth part.

There is no instance of a deep sea cable that was perfect when laid having failed in deep water. The Malta and Alexandria Line is laid in three sections, and the one laid in deep sea from Malta to Tripoli has never cost sixpence for repairs. The injuries have all been, with one exception, between Bengazi and Alexandria, where the cable is laid in shallow water, and where it has had to be repaired each time it has been chafed by the rocks. In the new Atlantic Cable the shore ends will be carried sufficiently far out to reach into deep water, and we have no instance on record of a cable approaching to the weight of this shore end having been injured. The lines once laid perfectly will, in all probability, be permanent.

With the Atlantic Cable, which I have every confidence will be laid this year, and the half cable (now in a perfect state at the bottom of the sea) completed, there will be complete freedom with these lines from the delays and errors experienced in our Indian telegrams. The communication from London to Valentia will be direct at one leap, Valentia to Newfoundland in a second leap, and Newfoundland to New York in one or at most in two leaps. When one cable is successfully laid, it is certain to be quickly followed by others. The Newfoundland Company contemplate constructing two additional wires by different routes, so that there shall be several means of communication throughout the distance, and I for one shall be sadly disappointed if messages from London to New York do not reach their destination long in advance of time.

The lines will be all under the management of joint stock companies, whose interest it will be to secure the highest speed and efficiency, and the countries through which the lines will pass speak our own language, an inestimable advantage as regards accuracy * * *

(F.)

THE TARIFF THROUGH THE ATLANTIC CABLE.

London, September 1st, 1865.

MY DEAR SIR,

In the London Press, calculations of the profits of an Atlantic Cable have appeared, these calculations are based upon the idea of charging only 5s. a word.

A telegraph to be of use must be expeditious and accurate. It will, therefore, be necessary to limit the messages to be transmitted through the cable to such an extent that the number received during the twenty-four hours shall not exceed the carrying powers of the cable during that period of time. Should the number of messages received during the twenty-four hours exceed the transmitting powers of the cable the second day would begin with a portion of the messages left over from the first day, and in the course of a short time this daily accumulation would amount to so much that letters by mail would reach their destination sooner than messages by telegraph, as, by law, all messages must be sent in the order in which they were received.

There is only one legitimate way that I can see of limiting the messages that will pour in from every part of Europe, Asia, and Africa, to be transmitted to the whole of the North American Continent, and *vice versa*, and that is, to make the price such that it shall limit the messages sufficiently to keep them within the carrying power of the cable.

From an experience of over eighteen years, dating from the very commencement of the telegraph as a public institution, and from the experience gained by means of the submarine cables connecting Alexandria and Malta with Europe, I feel perfectly convinced that even a sum of 20s. per word will not limit the traffic sufficiently to keep the line between America and Europe free.

When we consider that the submarine line between Alexandria and Malta, which forms the connecting link between but a small part of Egypt and Europe, has a very large amount of business, how is it possible that two wires can do the business between Europe, Asia, and Africa on the one side, and America on the other? The manager of the Malta and Alexandria line recommended that a sum of £2 per word should be charged through the Atlantic Cable to limit the messages to the capacity of the line.

As soon as one line of communication is established between America and Europe it will undoubtedly have to be immediately followed by others to meet the increasing demand which experience shows invariably to follow the opening of telegraphic communication between distant points.

I am, Sir, yours faithfully,

C. F. VARLEY,

The Electrician of the Electric and International Telegraph Company.

CYRUS W. FIELD, Esq.,
Palace Hotel, BuckinghamGate.

(G.)

Copy.

Chatham, 14th February, 1866.

DEAR MR. FIELD,

In reply to your enquiry as to how I am getting on with my Telegraph Code, it will doubtless interest you to know that it is now rapidly approaching completion. When I made the trial through the 2300 miles of cable on board the Great Eastern, in July last, I succeeded in gaining 14 minutes out of 32 in the transmission of a message. The code at that time was incomplete.

Now I fully expect to be able to gain (at the lowest average) cent. per cent. over any instruments worked on the existing telegraphic system. Another advantage possessed by this code is its correctness in the rendering of telegrams, added to which is its simplicity.

I have proposed to the Telegraph Construction and Maintenance Company to open negociations for the commercial working of my code, not with the Atlantic Cable alone, but with other existing great lines, especially India; and I am induced to believe that by doubling the working powers of a line the market value of the shares must necessarily be advantageously influenced.

I hope to see you again shortly on the subject, meanwhile believe me,

Yours very truly,

(Signed) FRANK BOLTON.

CYRUS W. FIELD, Esq.,
Palace Hotel,
London.

(H.)

Mr. Willoughby Smith's *New System of testing a Submarine Cable electrically during its submersion.*

Mr. Willoughby Smith, of the Gutta Percha Works, who was on board the Great Eastern last year, and who saw the difficulties we had to contend with, has since his return devised quite a new system of testing a cable electrically during its submersion. Of the merits of this system there can be no question, as it has been thoroughly tried through the 1,000 knots of Atlantic Cable now on board the ship with perfect success. Professor Thomson and all the gentlemen competent to form an opinion upon the subject, speak of it in the highest terms.

The characteristic advantage of this system over all previous ones is, that the insulation test may be permanently maintained throughout the voyage on shore as well as on board, while tests for continuity may be freely made, and communication between ship and shore constantly kept up without interfering in any way with the insulation test, which is all important.

Should a fault in insulation take place, it is immediately discovered and readily localised; for, by the peculiar working of this system, the electricians on board and on shore are enabled to furnish each other with such data as to render the localisation of the fault comparatively easy.

Another advantage in this system may be mentioned, namely, the simplicity of all its arrangements. There is not throughout the entire voyage any alteration in the connections. Whatever takes place, there cannot be any confusion in the handling of the apparatus. Experience has shown that in the excitement of laying a submarine cable great trouble is caused by having to change the apparatus so frequently for the different tests; but in this new system all these tests are combined in one, and thus this great annoyance is completely obviated.

(I.)

1866.

List of voyages by Steamers crossing the North Atlantic between Europe and America yearly.

Name of Line.	Per Week each way.		Number per Annum.
Inman	2	......	208
Cunard	1	......	104
Montreal	1	......	104
National	1	......	104
British and American	1	......	104
	Every Two Weeks		
Cunard (Extra)	1	......	52
North German Lloyds	1	......	52
Hamburg American	1	......	52
Guion and Co.'s............	1	......	52
London and New York	1	......	52
London and Boston	1	......	52
Liverpool and Boston	1	......	52
Liverpool and Baltimore	1	......	52
Anchor	1	......	52
Trans-Atlantic (French)	1	......	52
	Every Four Weeks.		
North American Lloyd......	1	......	26
New York and Havre	1	......	26
		Total..	1,196

N.B.—On several of the above Lines it is intended to increase the number of passages, and new Companies are being formed.

NEW YORK, NEWFOUNDLAND

AND

LONDON TELEGRAPH COMPANY.

(Incorporated April 15th, 1854.)

PETER COOPER, Esq.	*President.*
CYRUS W. FIELD, Esq.	*Vice-President.*
MOSES TAYLOR, Esq.	*Treasurer.*
Professor S. F. B. MORSE	*Electrician.*
DAVID DUDLEY FIELD, Esq.	*Counsel.*

DIRECTORS.

PETER COOPER, Esq.	New York.
MOSES TAYLOR, Esq.	New York.
CYRUS W. FIELD, Esq.	New York.
MARSHALL O. ROBERTS, Esq.	New York.
WILSON G. HUNT, Esq.	New York.

SECRETARY.

ROBERT W. LOWBER, Esq.

GENERAL SUPERINTENDENT.

ALEXANDER M. MACKAY, Esq., St. John's, Newfoundland.

THE ATLANTIC TELEGRAPH COMPANY.

(Incorporated by Act of Parliament, 1857.)

DIRECTORS AND OFFICERS FOR 1866.

Directors.

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CURTIS M. LAMPSON, Esq., VICE-CHAIRMAN.

G. P. BIDDER, Esq., C.E.	SAMUEL GURNEY, Esq., M.P.
FRANCIS LE BRETON, Esq.	CAPTAIN A. T. HAMILTON.
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LORING ANDREWS, Esq.	New York.
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Consulting Scientific Committee.

WILLIAM FAIRBAIRN, Esq., F.R.S., Manchester.
CAPTAIN DOUGLAS GALTON, R.E., F.R.S., London.
PROFESSOR WILLIAM THOMSON, F.R.S., Glasgow.
PROFESSOR C. WHEATSTONE, F.R.S., London.
JOSEPH WHITWORTH, Esq., F.R.S., Manchester.

Honorary Consulting Engineer in America—
GENERAL MARSHALL LEFFERTS, New York.

OFFICES—12, ST. HELEN'S PLACE, BISHOPSGATE STREET WITHIN, LONDON.

Secretary and General Superintendent—GEORGE SAWARD, Esq.
Electrician—CROMWELL F. VARLEY, Esq.
Solicitors—MESSRS. FRESHFIELDS & NEWMAN.
Auditor—H. W. BLACKBURN, Esq., Bradford, Yorkshire, *Public Accountant.*

Bankers.

In London	The Bank of England, and Messrs. Glyn, Mills & Co.
In Lancashire	The Consolidated Bank, Limited, Manchester.
In Ireland	The National Bank and its Branches.
In Scotland	The British Linen Company and its Branches.
In New York	Messrs. Duncan, Sherman & Co.
In Canada and Nova Scotia	The Bank of British North America.
In Newfoundland	The Union Bank of Newfoundland.

(L.)

TELEGRAPH CONSTRUCTION AND MAINTENANCE COMPANY, LIMITED.

Uniting the Business of the Gutta Percha Company with that of Messrs. Glass, Elliot & Company.

DIRECTORS.

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ALEXANDER HENRY CAMPBELL, Esq., M.P., VICE-CHAIRMAN.
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THE CONSOLIDATED BANK, Limited, London and Manchester.

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Messrs. BAXTER, ROSE, NORTON & Co.

SECRETARY.

WILLIAM SHUTER, Esq.

OFFICES.

54, OLD BROAD STREET, LONDON.

WORKS.

WHARF ROAD, CITY ROAD, N., AND EAST GREENWICH, S.E.

(M.)

THE

GREAT EASTERN STEAM SHIP COMPANY,

LIMITED.

DIRECTORS.

DANIEL GOOCH, Esq., M.P., Chairman.
WILLIAM BARBER, Esq.
THOMAS BRASSEY, Jun., Esq.

SECRETARY.

J. H. YATES, Esq., 26, Castle Street, Liverpool.

(N.)

MESSRS. J. S. MORGAN & Co., *London*,

Are prepared to receive Subscriptions for Shares in the

ANGLO-AMERICAN
TELEGRAPH COMPANY LIMITED.

Incorporated under the "Companies' Act, 1862," which limits the liability of each Shareholder to the amount of the Shares subscribed by him.

CAPITAL £600,000 in 60,000 SHARES of £10 EACH.

Deposit on Application	£1
Deposit on Allotment	£3
16th April	£3
1st June	£3
	£10

Under arrangements with the Atlantic Telegraph Company, this Company will be entitled to receive **£125,000** *per annum out of the earnings from the working of the Atlantic Telegraph Company's Lines, and they will also be entitled to receive* **£25,000** *per annum from the New York, Newfoundland and London Telegraph Company, out of the earnings of that Company for through Messages.*

The agreements between the Companies provide for other contingent advantages.

Directors.

GEORGE PEABODY, Esq., 22, Old Broad Street.
EDWARD CROPPER, Esq., Swaylands, Penshurst.
CAPTAIN A. T. HAMILTON, 12, Bolton Row, Piccadilly.
RICHARD ATWOOD GLASS, Esq., Ashurst, Dorking.
DANIEL GOOCH, Esq., M.P., Clewer Park, Windsor.
HENRY BEWLEY, Esq., Willow Park, Dublin.
FRANCIS A. BEVAN, Esq., 54, Lombard Street.
J. R. M'CLEAN, Esq., C.E., 23, Great George Street, Westminster.
CHARLES E. STEWART, Esq., 102, Lancaster Gate, Hyde Park, W.

Bankers.

Messrs. BARCLAY, BEVAN, TRITTON, TWELLS & Co.,
54, Lombard Street, E.C.

Secretary *(pro tem)*.—J. C. DEANE, Esq.

SUBMARINE TELEGRAPH CABLES now in successful working order, the Insulated Wires for which were manufactured by the Gutta Percha Company, Patentees, Wharf Road, City Road, London.

March, 1866.

No.	Date when laid.	From	To	No. of Conductors.	Length of Cable in Statute Miles.	Length of Insulated Wire in Statute Miles.	Depth of Water in Fathoms	Length of time the Cables have been working.
1	1851	Dover	Calais	4	27	108	..	15 years
2	1853	Denmark, across the Belt		3	18	54	..	13 years
3	1853	Dover	Ostend	6	80½	483	..	13 years
4	1853	Frith of Forth		4	6	24	..	13 years
5	1853	Portpatrick	Donaghadee	6	25	150	..	13 years
6	1853	Across River Tay		4	2	8	..	13 years
7	1854	Portpatrick	Whitehead	6	27	162	..	12 years
8	1854	Sweden	Denmark	3	12	36	14	12 years
9	1854	Italy	Corsica	6	110	660	325	12 years
10	1854	Corsica	Sardinia	6	10	60	20	12 years
11	1855	Egypt		4	10	40	..	11 years
12	1855	Italy	Sicily	3	5	15	27	11 years
13	1856	Straight of Canso	Cape Breton, N.S.	3	1½	4½	..	10 years
14	1857	Norway ... across	Fiords	1	49	49	300	9 years
15	1857	Across mouths of Danube		1	3	3	..	9 years
16	1857	Ceylon	Mainland of India	1	30	30	..	9 years
17	1858	Italy	Sicily	1	8	8	60	8 years
18	1858	England	Holland	4	140	560	30	8 years
19	1858	Ditto	Hanover	2	280	560	30	8 years
20	1858	Norway ... across	Fiords	1	16	16	300	8 years
21	1858	South Australia	King's Island	1	140	140	45	8 years
22	1858	Ceylon	India	1	30	30	45	8 years
23	1859	Alexandria		4	2	8	..	7 years
24	1859	England	Denmark	3	368	1104	30	7 years
25	1859	Sweden	Gothland	1	64	64	80	7 years
26	1859	Folkestone	Boulogne	6	24	144	32	7 years
27	1859	Across rivers in India		1	10	10	..	7 years
28	1859	Malta	Sicily	1	60	60	79	7 years
29	1859	England	Isle of Man	1	36	36	30	7 years
30	1859	Suez	Jubal Island	1	220	220	..	7 years
31	1859	Jersey	Pirou, France	1	21	21	15	6 years
32	1859	Tasmania	Bass' Straits	1	240	240	..	6 years
33	1860	Denmark	(Great Belt) {14 miles / 14 miles	6 / 3	28	126	18	6 years
34	1860	Dacca	Pegu	1	116	116	..	6 years
35	1860	Barcelona	Mahon	1	180	180	1400	6 years
36	1860	Minorca	Majorca	2	35	70	250	6 years
37	1860	Iviza	Majorca	2	74	148	500	6 years
38	1860	St. Antonio	Iviza	2	76	152	450	6 years
39	1861	Norway ... across	Fiords	1	16	16	300	5 years
40	1861	Toulon	Corsica	1	195	195	1550	5 years
41	1861	Holyhead	Howth, Ireland	1	64	64		5 years
42	1861	Malta	Alexandria	1	1535	1535	420	5 years
43	1861	Newhaven	Dieppe	4	80	320	..	5 years
44	1862	Pembroke	Wexford	4	63	252	58	4 years
45	1862	Firth of Forth		4	6	24	..	4 years
46	1862	England	Holland	4	130	520	30	3½ years
47	1862	Across River Tay		4	2	8	..	4 years
48	1863	Sardinia	Sicily	1	243	243	1200	3 years
49	1864	Persian Gulf		1	1450	1450	120	2 years
50	1864	Otranto	Avlona	1	60	60	569	1½ years
51	1865	La Calle	Biserte	1	97¼	97¼	..	12 months
52	1865	Sweden	Prussia	3	55	166	..	12 months
53	1865	Biserte	Marsala	1	164¼	164¼	..	12 months
54	1865	Corsica	Tuscany	1	66	66	..	6 months
			TOTAL ..		6811	11080½		

A great many Cables of short lengths, not included in this List, are now at work in various parts of the world; and other Cables, the Wires Insulated by the Gutta Percha Company, have been laid by Messrs. FELTEN & GUILLEAUME, of Cologne, during the last eight years, amount to over 1,000 miles, and which are now in working order.

LONDON:
WILLIAM BROWN & CO., PRINTERS,
OLD BROAD STREET.

ny in 1858, and of the Cable manufactured for the same
, and the Gutta Percha Company.)

LES.

NEW ATLANTIC CABLE, 1866.

CONDUCTOR—Copper strand consisting of 7 wires (6 laid round one), and weighing 300 lbs. per nautical mile, embedded for solidity in Chatterton's Compound. Gauge of single wire ·048 = ordinary 18 gauge. Gauge of strand ·144 = ordinary No. 10 gauge.

INSULATION—Gutta Percha, 4 layers of which are laid on alternately with four thin layers of Chatterton's Compound. The weight of the entire insulation 400 lbs. per nautical mile. Diameter of core ·464, circumference of core 1·392.

EXTERNAL PROTECTION—Ten solid wires of the gauge ·095, (No. 13 gauge) drawn from Webster and Horsfall's Homogeneous Iron, and galvanized, each wire surrounded separately with five strands of white Manilla Yarn, and the whole laid spirally round the core, which latter is padded with Jute yarn, saturated with preservative mixture.

WEIGHT IN AIR—31 cwt. per nautical mile.

WEIGHT IN WATER—14¾ cwt. per nautical mile.

BREAKING STRAIN—8 tons 2 cwt., or equal to eleven times its weight in water per nautical mile; that is to say, the cable will bear its own